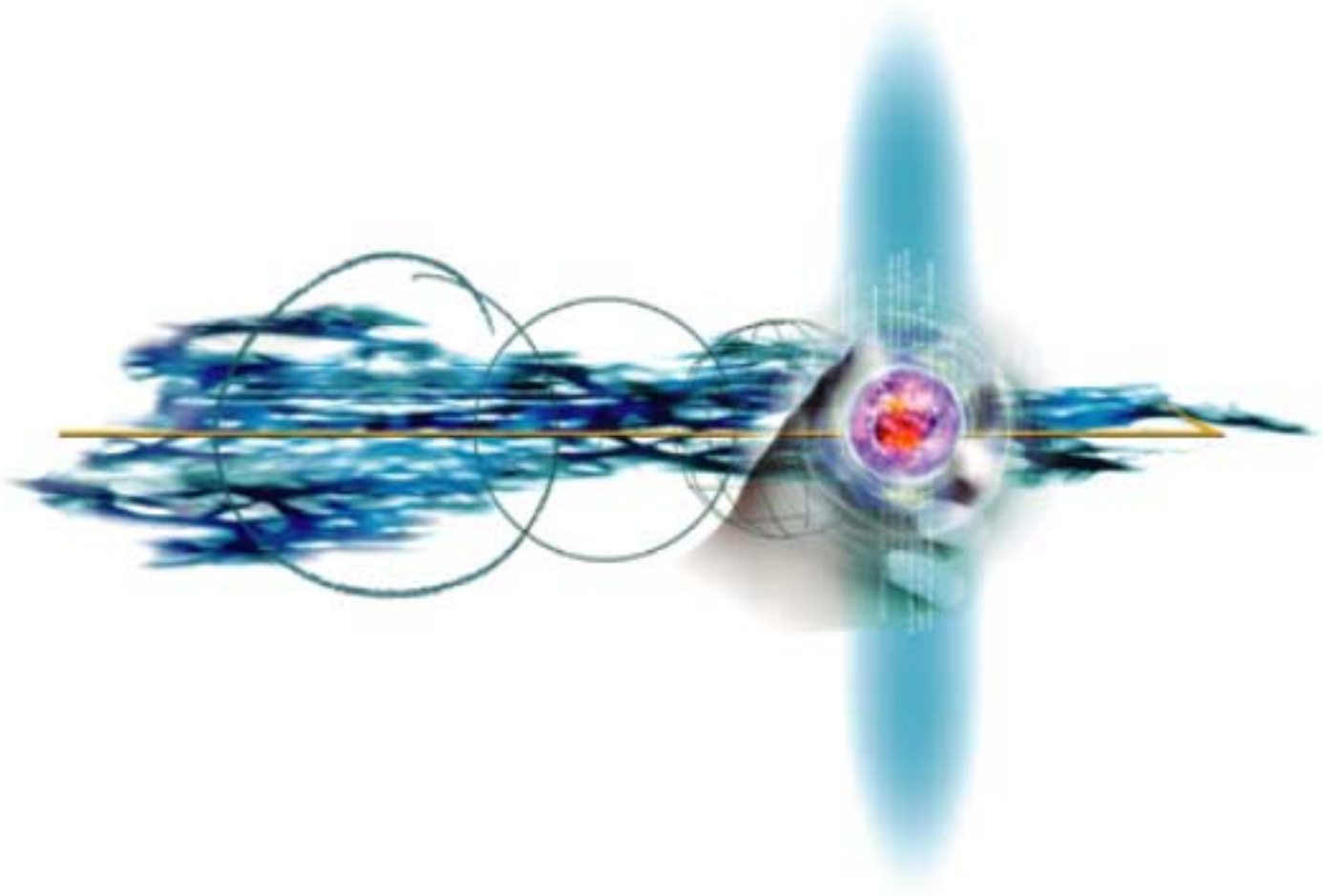

RC100 User Manual

Version 1.2

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>: Conventions

Conventions

A number of conventions are used in this document. These conventions are detailed below.

Warning Message. These messages warn you that actions may damage your hardware.

Handy Note. These messages draw your attention to crucial pieces of information.

Hexadecimal numbers will appear throughout this document. The convention used is that of prefixing the number with '0x' in common with standard C syntax.

Sections of code or commands that you must type are given in typewriter font like this:

```
void main();
```

Information about a type of object you must specify is given in italics like this:

`copy` *SourceFileName DestinationFileName*

Optional elements are enclosed in square brackets like this:

`struct` [*type_Name*]

Curly brackets around an element show that it is optional but it may be repeated any number of times.

>: Assumptions

Assumptions

This manual assumes that you:

- have used or have the language reference for Handel-C
- are familiar with common programming terms (e.g., functions)
- are familiar with MS Windows

Omissions

This manual does not include:

- instruction in VHDL
- instruction in the use of place and route tools

>: 1. Overview

>: 1 Overview

1.1 Introduction

The RC100 Board is a development board designed to be helpful in the learning of the Handel-C language.

This manual describes:

- running the demos pre-installed on the RC100 board
- using the File Transfer Utility program to transfer bit files to the FPGA, and to read and write data to the Flash RAM on the board.
- using and modifying the examples. These programs demonstrate some of the features of Handel-C such as the par statement, pipelining and channels.

Further information about the RC100 is available in the

RC100 Hardware Manual

RC100 Library Reference Manual

RC100 Tutorial Manual

1.2 RC100 features

1.2.1 Programmable logic chips

The RC100 Board contains two programmable logic chips:

- **XILINX Spartan II FPGA**: 200Kgates Spartan II FPGA in a FG-456-pin package. The Spartan II FPGA is the main repository of programmable logic on the RC100 Board.
- **XILINX XCR3128XL CPLD**: The CPLD (Complex programmable logic device) is used to manage the configuration of the Spartan II FPGA via the parallel port or Flash RAM.

>: 1. Overview

1.2.2 Other devices on the board

Device	Function
8 Mbytes of Flash RAM	Stores multiple configurations or general-purpose data for the FPGA
Two independent 256K x 36 SSRAM banks	Used by the FPGA for general-purpose data storage.
Philips SAA7111A EVIP video decoder	Accepts NTSC/PAL/SECAM signals through an RCA jack or S-video connector and outputs RGB signal to the FPGA.
DAC (Digital to Analogue Converter) with a 24-bit colourmap	Used by the FPGA to output video to a VGA monitor
Two mouse/keyboard PS2 ports	Give the FPGA access to common PC input devices.
Parallel port interface	Used for programming the FPGA and Flash RAM and for bi-directional communication.

1.3 References

This manual contains references to the following documents:

1. RC100 Installation Guide
   Celoxica, 2001
2. RC100 Function Library Manual
   Celoxica, 2001
3. RC100 Tutorial Manual
   Celoxica, 2001
4. RC100 Hardware Manual
   Celoxica, 2001
5. Handel-C Language Reference Manual (contained within the online help for DK1)
   Celoxica, 2000

>: 2. Demonstrations provided

>: 2 Demonstrations provided

2.1 Introduction

The demonstration programs that are pre-installed on the RC100 Board are provided for testing and demonstrating the RC100 Board. Note that the source code is not available for these demonstrations except for the Breakout and Celoni racer programs, which are provided as tutorials. See the *RC100 Tutorial Manual* for more information on the tutorials.

The demonstration programs are stored on the board in Flash RAM. If you overwrite the demonstrations, you can upload them again by using the File Transfer Utility (Section 3.2).

To use the demos, set up the board:

1. Make sure that the Autoboot switch is on, and all the others are off. For more information about switches, refer to the *RC100 Hardware manual*.
2. Connect a PS2 mouse, monitor, camera and power supply to the board. Set the monitor to a 640 * 480 display.
3. Switch on the power.

You will see the Menu Screen displayed on your monitor. The Menu Screen allows you to select the other demos.

Note that the peripheral devices should be connected before the RC100 Board is turned on. Otherwise the devices may not function correctly.

2.1.1 Menu screen for RC100 demonstrations

This application is used as a menu system for selecting all other demonstration programs. You can select the other programs by moving the mouse over the appropriate text and clicking the left mouse button.

>: 2. Demonstrations provided

Parallel processing

The menu screen demo shows how important parallel computing is when running at a low clock frequency. The demo is mixing the rotating background with the moving lights, the text and the logo. This is possible because the calculations for each procedure are done in parallel.

The video stream is generated at a rate of one pixel per clock cycle, so no video buffer is required.

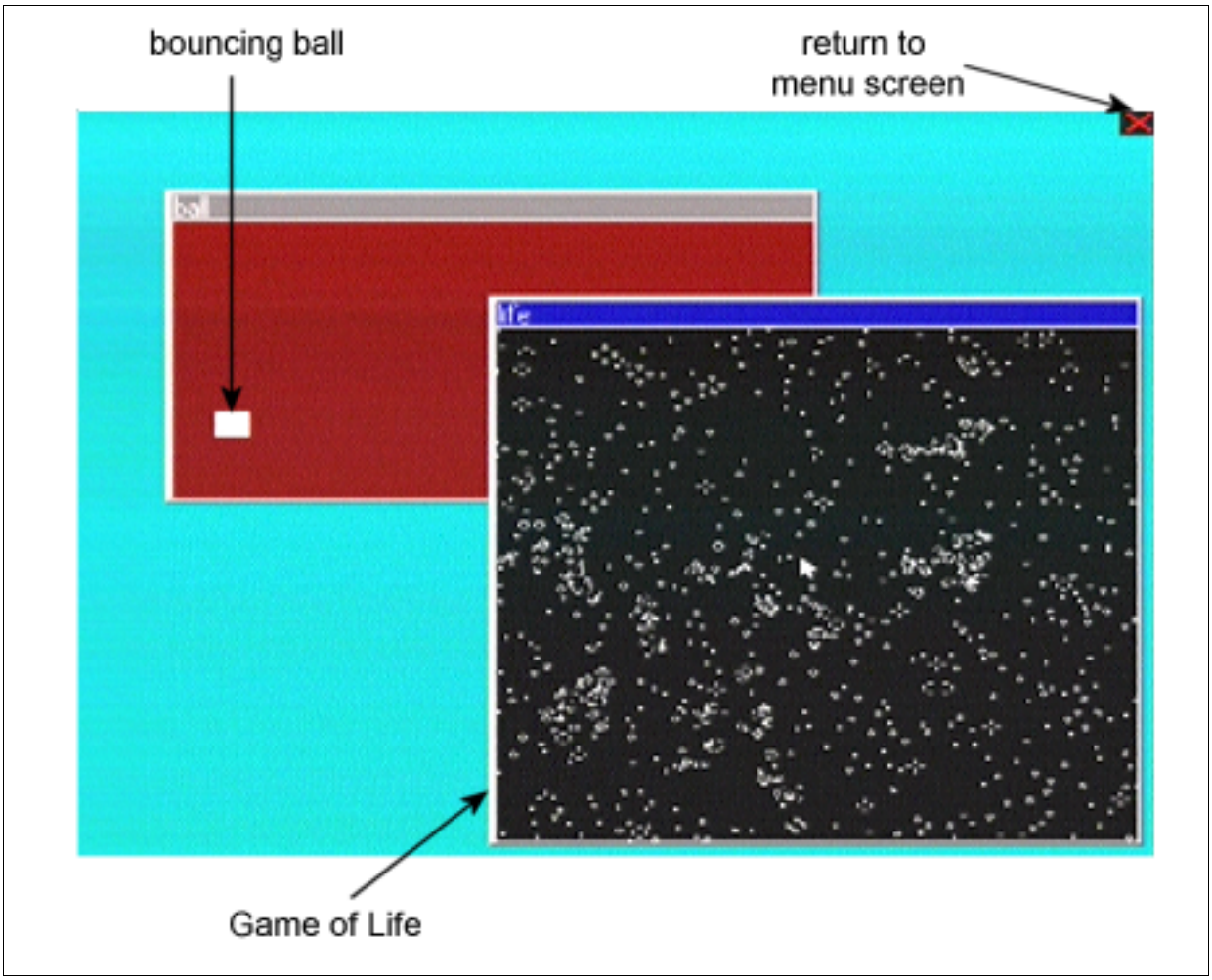
2.1.2 Windows

This demo displays two windows. One contains a bouncing ball and the other contains a demonstration of the classic computer science problem popularly known as the “Conway’s Game of Life”.

- You can use the mouse to move the windows around.
- You can click the right mouse button in the window with the bouncing ball to alternate between a transparent and opaque background.

>: 2. Demonstrations provided

- To start the game of life, click the left mouse button anywhere in the “Life” window. Each individual element survives according to the number of neighbours it has. It dies if there are too many or too few.
- Once the game has started, you can click the left mouse button to spawn life. If you press the right mouse button, the screen is cleared. If you press both mouse buttons together the screen will pause, enabling you to use the right button to single step through the life process. To resume normal play, press both mouse buttons together.
- To return to the menu screen, click the cross in the top right corner.



Parallel processing

This is another demonstration of the power of parallelism. You'll notice as you move the windows around that the animations inside do not glitch, no matter how fast you move the

mouse. This is because each window is being generated by a completely separate piece of hardware on the FPGA. If this demonstration were implemented on a real-time operating system, you would be able to notice decreased performance as the windows were moved around.

Video management

The program "scans" the screen area and decides what colour the pixel at the current position should be, depending on what the window processes are doing.

The video stream is generated at a rate of one pixel per clock cycle, so no video buffer is required.

2.1.3 Venus de Milo

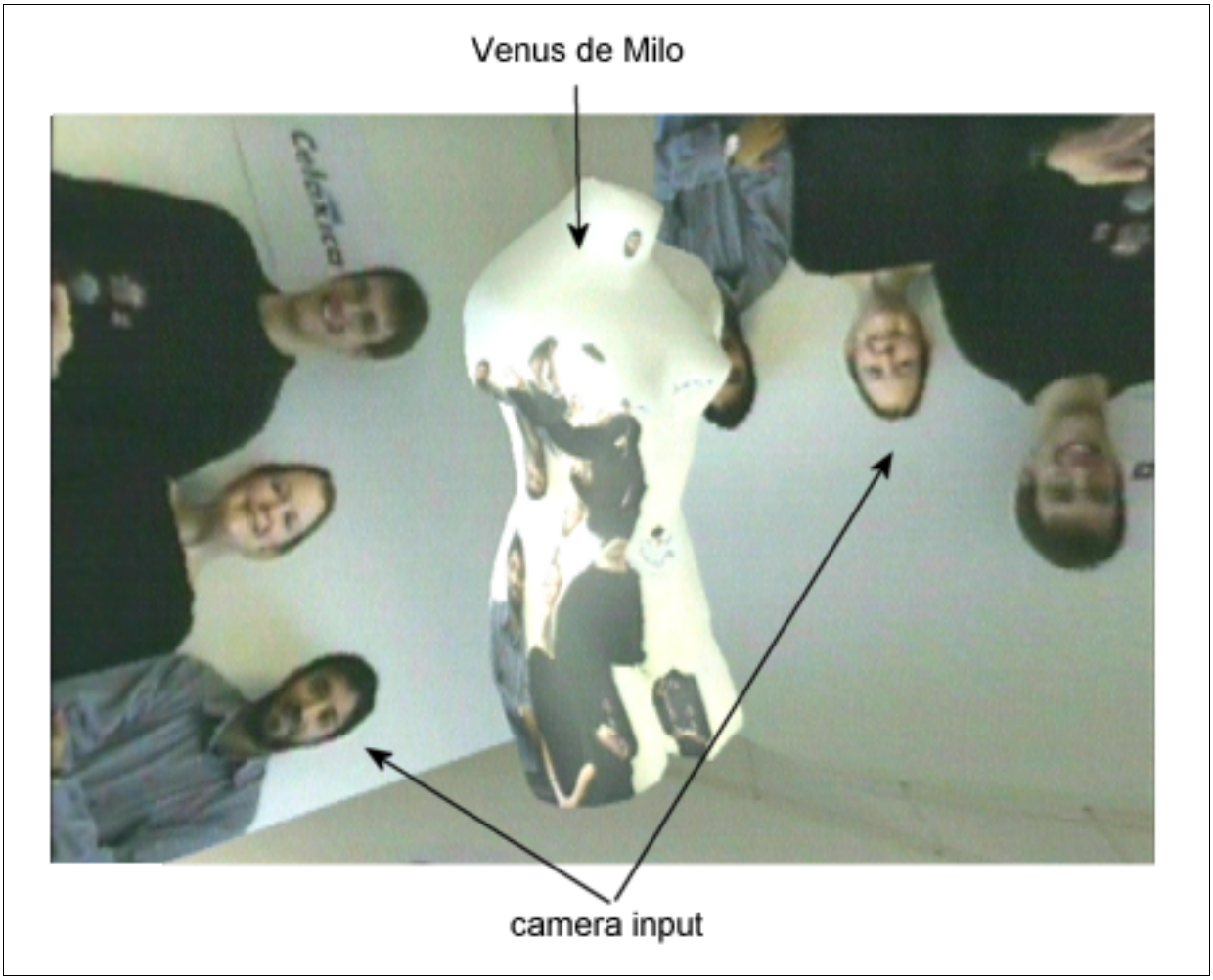
This program uses video from the camera and displays it in a rotating room with the Venus de Milo as the centrepiece.

To stop or start the rotation at any time click the left mouse button.

To return to the menu screen right click the right mouse button while the Venus de Milo is rotating.

If there is no input from the camera, a grey box rotates around the Venus de Milo.

>: 2. Demonstrations provided



This demo displays a complex graphical image, rotating within a room, while displaying and processing live video.

The FPGA generates one pixel per clock cycle, giving a frame rate of 60fps.

To do this type of processing you would usually need a very high performance processor. Techniques used to achieve this rely on Handel-C features, such as parallelism, pipelining, and adjustable width variables. For information how to use these, refer to the *RC100 Tutorial manual* or to the online help supplied with DK1.

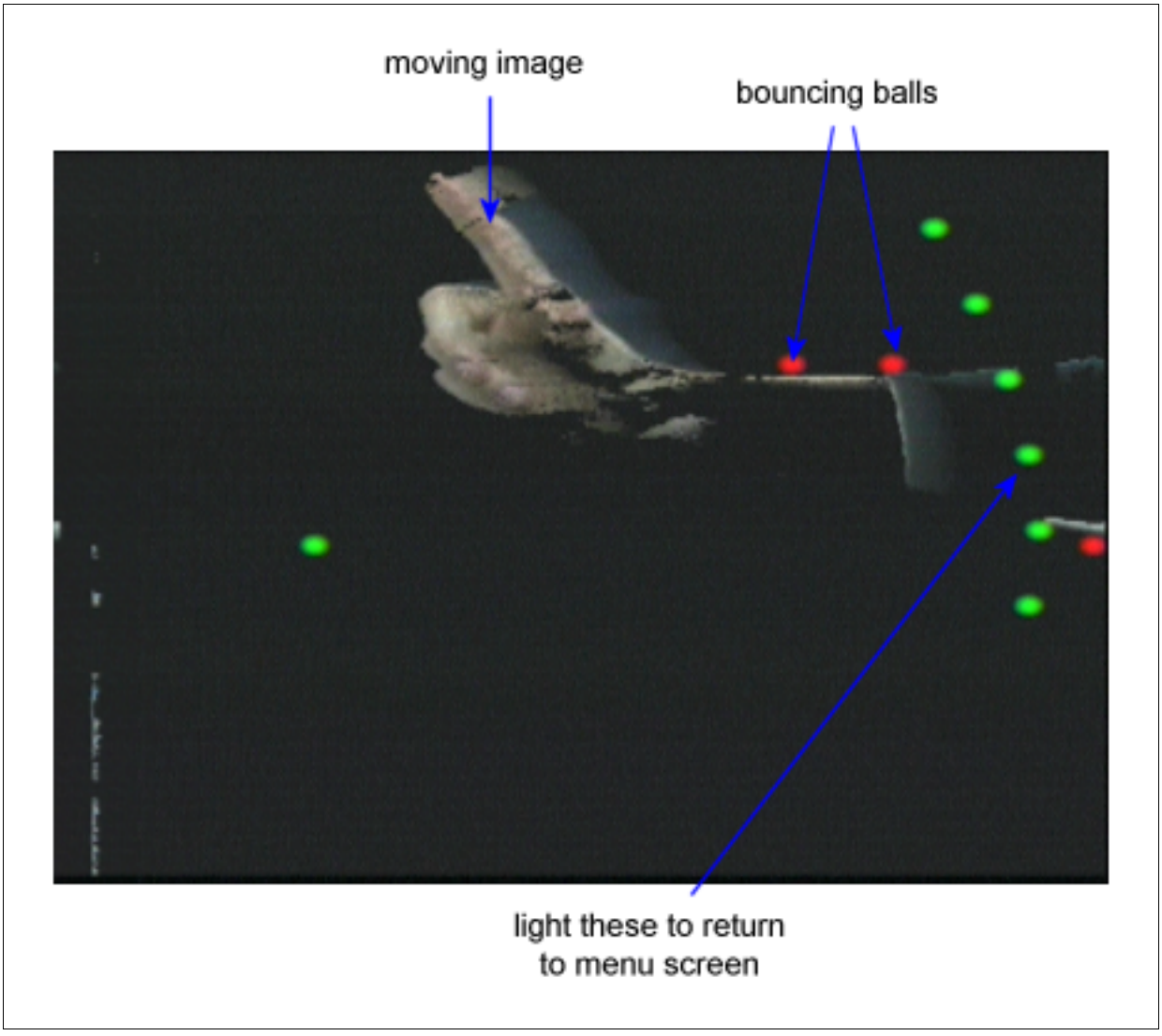
2.1.4 Video processing

The video processing program detects moving objects and displays them in colour. Stationary objects are displayed in dark grey.

>: 2. Demonstrations provided

Input from the camera is combined with a screen showing moving balls. If the balls are “hit” by a moving image (received from the camera) they bounce and change colour from green to red.

To return to the menu screen, use the moving object in front of the camera (e.g. your hand) to touch each of the stationary balls on the right side of the screen in order from top to bottom.



Information

This program compares previous images from the camera with the current image. The image-processing is performed in real time and would require a high performance processor to perform the same task on a standard PC.

>: 2. Demonstrations provided

2.1.5 Squishy

The squishy program allows you to stretch regions of an image by selecting and dragging them with a mouse pointer.

- Left-click the mouse button to grab the parts of the image and keep the left mouse button pressed down whilst you stretch them out.
- To reset the image to normal, left-click the R in the top left corner.
- To return to the menu screen left-click the cross in the top right corner.

Image manipulation

The FPGA on the board is configured to implement the mouse and video drivers, as well as to perform the image-processing required for the game.

The image is morphed between the original image and the adjusted image using a sine function and a vector map. The offsets of the image are calculated in real time, and the video stream is generated at a rate of one pixel per clock cycle, so no video buffer is required.

The external memory is only used to store the image and the offset vectors.

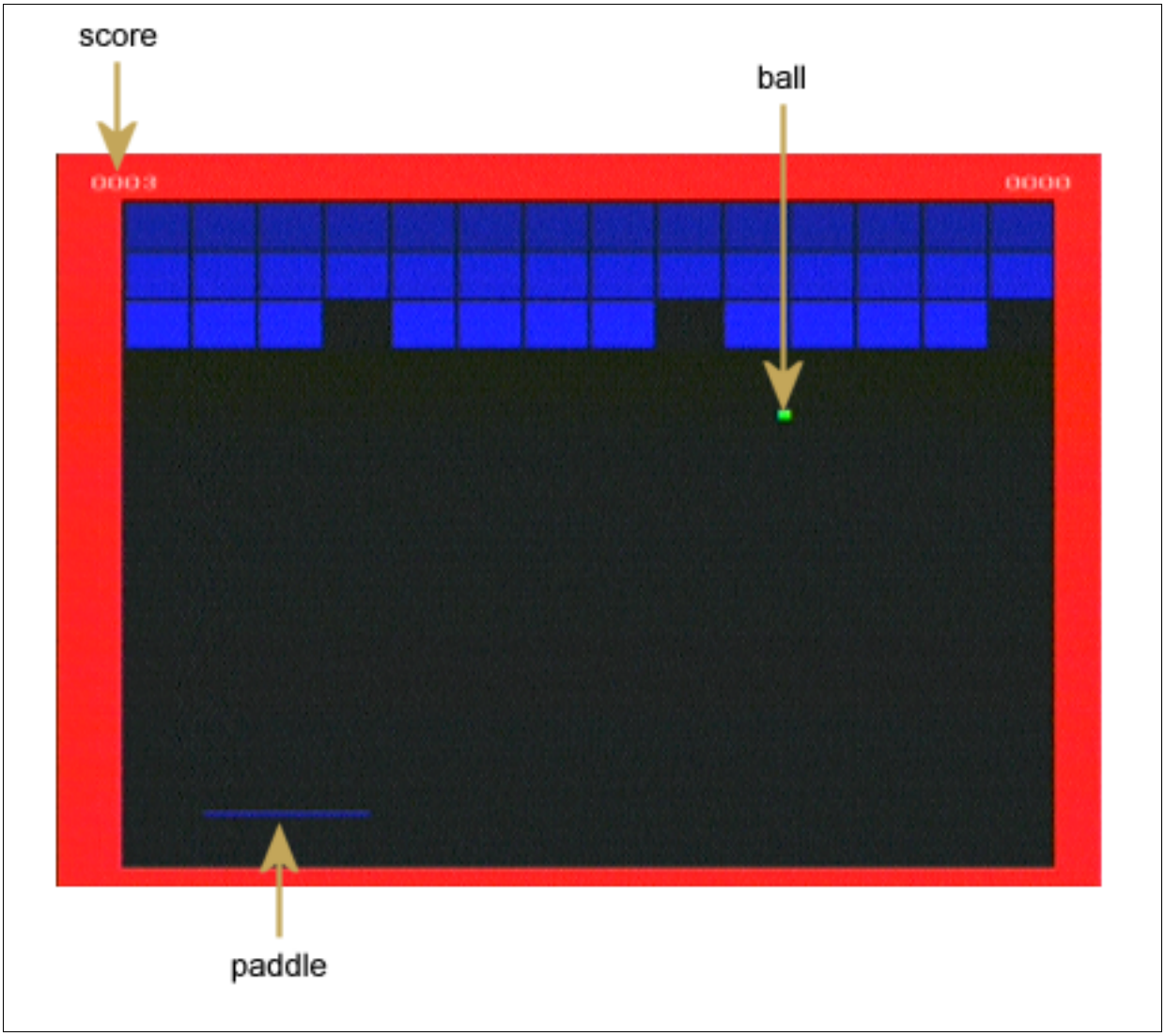
2.1.6 Breakout

This is the traditional breakout game.

- To start the game press the left mouse button.
- Move the mouse to control the paddle. You knock the ball against the bricks to eliminate them and get points. If the ball hits the bottom line it is lost. Your current score is shown in the top left corner and the previous highest score is in the top right corner. Each time you play you get 3 balls. When the game is over the ball stays in the centre of the screen.
- Use the left mouse button to restart the game.

>: 2. Demonstrations provided

- To return to the menu screen at any time, click the right mouse button.



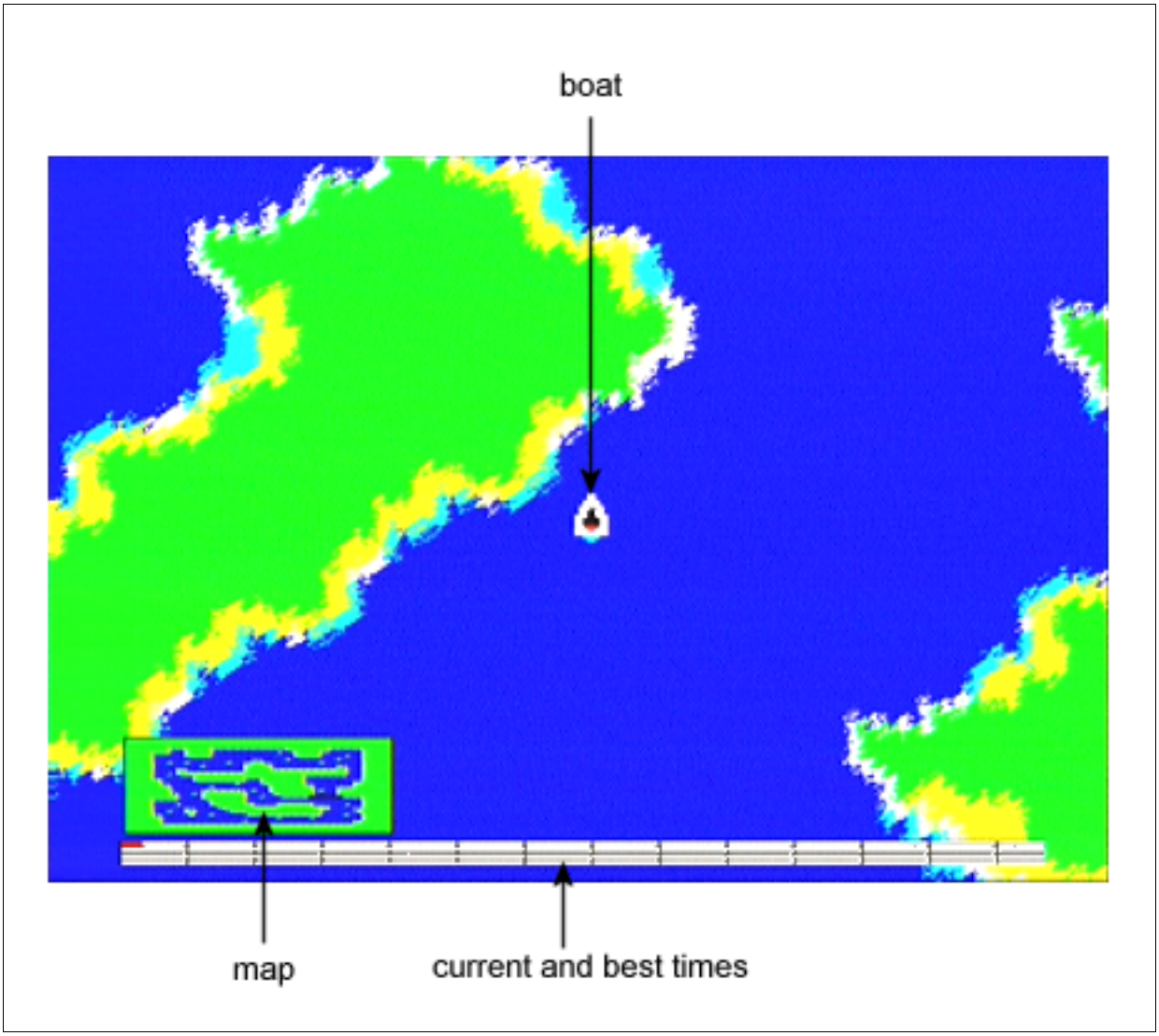
Information

The FPGA on the RC100 Board has been configured to implement the mouse and video driver in parallel with the processing required for the game. The video stream is generated at a rate of one pixel per clock cycle, so no video buffer is used.

2.1.7 Boat Game

The aim of this game is to get the boat to the finish line without crashing. The boat travels forward at a constant speed and it is your job to steer it through the water system.

>: 2. Demonstrations provided



Click the left and right mouse buttons on the mouse to steer the boat.

Once you've completed the course or have crashed the boat, you can restart the game by clicking the left mouse button or exit and return to the menu screen by clicking the right mouse button. There is a small delay between when you crash and when you can restart the game so that accidental resets do not occur.

There is a map of the course in the bottom left hand corner of the screen.

At the bottom of the screen are several bars. The first shows your time for the current game and the others show the best times achieved during the session.

>: 2. Demonstrations provided

Information

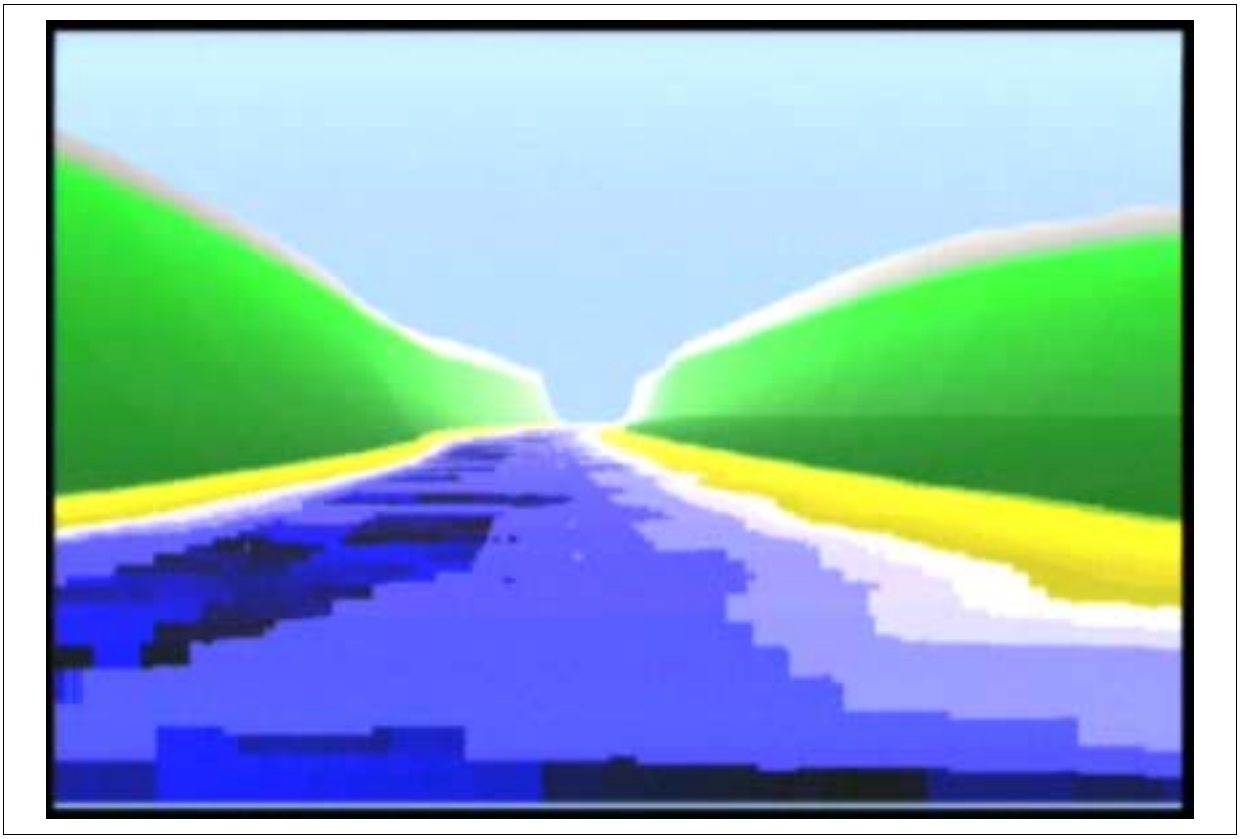
The FPGA on the board is configured to implement the mouse and video drivers in parallel with the processing required for the game. The rotation angles and angular velocity of the boat are all calculated in real time, which results in very smooth rotation compared to a similar game played on a computer. The video stream is generated at a rate of one pixel per clock cycle, so no video buffer is required. This demo does not use the SSRAM chips on the board. The map image is loaded from Flash RAM.

2.1.8 Celoni racer

This is like a 3D version of the boat game.

- Drive the vessel around the course. You don't need to worry about crashing, as you rebound off the banks if you hit them.
- Move the mouse to turn left and right and use the left mouse button to accelerate.
- You can return to the menu screen by clicking the right mouse button.

>: 2. Demonstrations provided



Information

The game demonstrates a number of important techniques for producing high-performance hardware using Handel-C. The FPGA on the board has been configured to implement the mouse and video drivers in parallel with the processing required for the game.

The landscape in the game is represented using a height-map (or height-field). This is a two-dimensional grid with each point on the grid having an associated height, similar to a top-down contour map. The map image is loaded from Flash RAM. The video stream is generated at a rate of one pixel per clock cycle, which produces a frame rate of 60fps.

This application is described in more detail in the *RC100 Tutorial Manual*.

2.2 Reloading the demonstrations

The demos are stored on the board in Flash RAM. If you overwrite the demos, you can transfer them onto the board again by using the File Transfer Utility (Section 3.2).

A script file (**`Load Demos Script.txt`**) is provided with all the commands necessary to transfer the data. The default location for the file is **`RC100/Demos.`**

>: 2. Demonstrations provided

You can execute this script by pressing the **Use Script** button on the main File Transfer Utility dialog (Section 3.3.3).

A map of the locations of the demonstrations in Flash RAM is given in Appendix B.

>: 3. Transferring files

>: 3 Transferring files

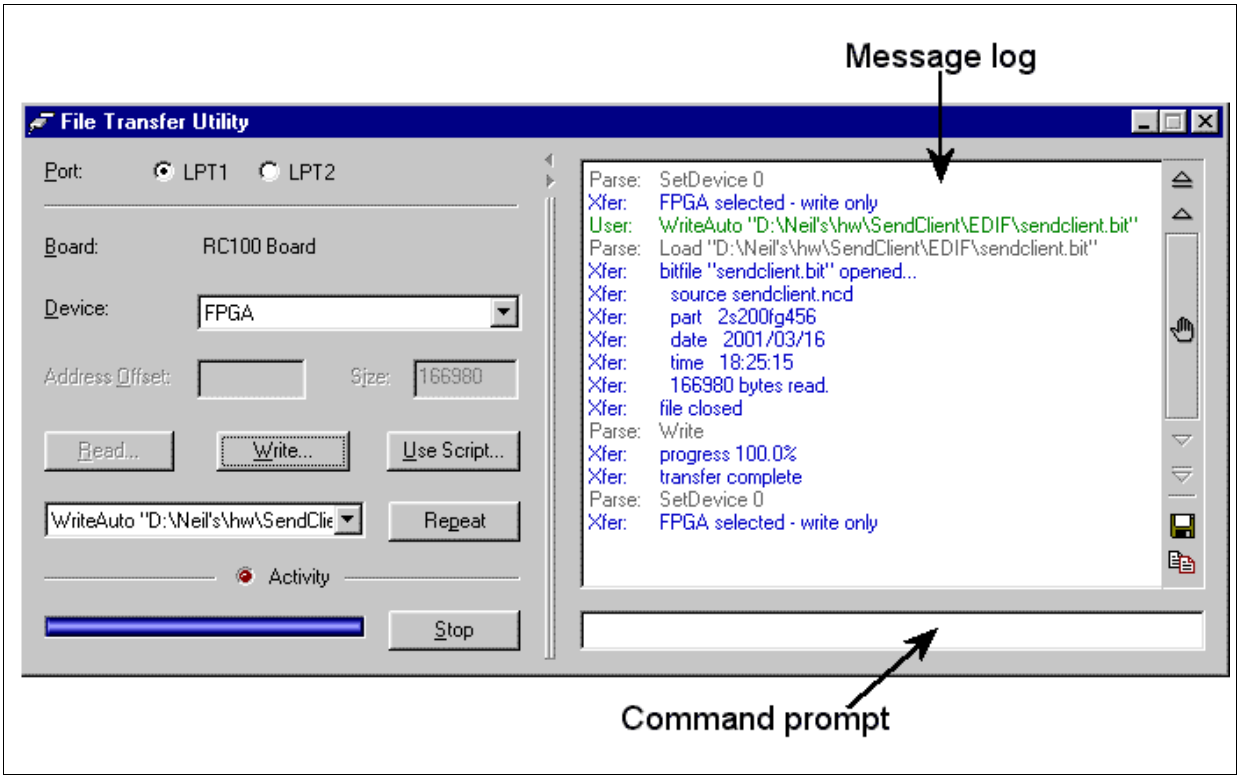
3.1 Introduction

The Celoxica File Transfer Utility allows you to transfer your files between your PC and the RC100 board via a parallel port cable.

This allows you to test new Handel-C designs by:

- transferring an FPGA configuration file directly to the FPGA on the RC100 Board
- transferring completed Handel-C designs to the RC100 board's Flash memory for future execution.

You also need to use the File Transfer Utility to run the software examples and the tutorials provided in the RC100 support software.



You can configure the File Transfer Utility and execute file transfers in three ways:

- select commands using the GUI
- type commands into the command prompt built into the main File Transfer Utility dialog

>: 3. Transferring files

- run a script file containing commands

The message log stores a list of recently executed commands.

3.1.1 DriverLINX device driver

The program uses the DriverLINX device driver that is provided on the RC100 Software Support CD. The latest version can be downloaded without charge from the Scientific Software Tools, Inc. website:

http://www.sstnet.com.

3.1.2 File Transfer Utility performance

It takes approximately 5 seconds per megabyte to transfer a configuration file to the FPGA. Data is written to the Flash memory at approximately 60 seconds per megabyte. The performance of the File Transfer Utility program may be reduced if you have a PC that is significantly below the recommended system requirements.

3.2 Transferring files

You can use the File Transfer Utility to:

- Transfer Xilinx® BIT files to the FPGA
- Transfer files or raw data from your PC to a specified location in the Flash RAM
- Transfer files or raw data from the Flash RAM to your PC

3.2.1 Configuring the File Transfer Utility

1. Connect the RC100 board to the parallel port on your PC with an IEEE 1284 compliant cable.
2. Switch on the board.
3. Start the File transfer program by selecting **Start>Programs>RC100>File Transfer Utility**.
4. Ensure the correct parallel port is selected. The program automatically detects ports at locations 378h (**LPT1)** and 278h (**LPT2).** If your port is at a non-standard location, type:
   SetPPTBase *Address*
   at the command prompt, where *Address* is the location of the port. Specify the address as either a decimal or a hexadecimal number.

>: 3. Transferring files

3.2.2 Transferring files to Flash RAM

1. Configure the File Transfer Utility as described above.
2. Select **Flash** from the **Device** drop-down list.
3. Specify the Flash location you want to transfer the file to by entering a decimal or hexadecimal number in the **Address Offset** box.

By default, the program will write to location zero in the Flash memory (the 'boot' sector).

4. Click **Write**. This opens the **Open file** dialog.
5. Browse and select the file you want to transfer to Flash RAM. The transfer will begin immediately, and the activity indicator will light up. You will see information about the progress of the data transfer in the message log.

Do not disconnect the board from the PC whilst the activity indicator is lit.

3.2.3 Transferring files to the FPGA

1. Configure the File Transfer Utility as described above.
2. Select **FPGA** from the **Device** drop-down list
3. Click **Write**. This causes the **Open file** dialog to appear.
4. Browse and select the file you want to transfer to the FPGA. The transfer will begin immediately. The activity indicator lights whilst data is being transferred. You will also see information about the progress of the data transfer in the message log window.

3.2.4 Transferring files from the board to your PC

1. Configure the File Transfer Utility as described above.
2. Select **Flash** from the **Device** drop-down list
3. Specify the location of the file you want to read in the **Address offset** box.
4. Enter the exact number of bytes of the file you want to read in the **Size** box.
5. Click **Read**. This opens the **Save As** dialog box.
6. Browse to select the directory where you want to save the file.
7. Enter the filename you want to use. The transfer will begin immediately. The activity indicator lights whilst data is being transferred. You will also see information about the progress of the data transfer in the message log window.

>: 3. Transferring files

3.2.5 Stopping a transfer

You can stop a file transfer at any time by clicking the **Stop** button.

3.3 Using commands and script files

You can type commands at the command prompt in the main File Transfer Utility dialog, or execute them from a script file. They will be interpreted by the command parser, and acted upon accordingly.

If you mistype a command or if the parameters are invalid, it will simply be ignored by the command parser. The command parser is not case-sensitive.

You can repeat recently executed commands by selecting them from the drop-down list box next to the **Repeat** button, then clicking **Repeat**.

You can recall commands typed at the command prompt by pressing the up or down arrow keys.

The message log displays previously executed commands and any messages generated in response. You can copy these into a text file or onto a clipboard (Section 3.4.1).

>: 3. Transferring files

3.3.1 File Transfer Utility commands

Command	Function
AutoDetect	Initiates automatic board detection process.
SetDevice *DeviceNumber*	Sets the active device to Flash RAM or FPGA. The numeric argument to this command is the zero-based index into this list.
SetOffset *MemoryLocation*	Sets the start location for a data file prior to transferring it to Flash memory.
SetFileSize *SizeInBytes*	Sets the required buffer size, prior to transferring raw data from the board.
Load *FileName*	Loads a file into the buffer, ready for transmission to the board.
Save *FileName*	Saves the current buffer contents to disk.
Write	Sends the current buffer contents to the board.
Read	Initiates a transfer of data from the board to the buffer.
WriteAuto *FileName*	Compound instruction that loads the specified file, then writes it to the currently selected device.
ReadAuto *FileName*	Compound instruction that reads data from the currently selected device and saves the buffer to the given file name.
SetLPT *LPTNumber*	Selects the parallel port by LPT number.
SetPPTBase *Address*	Selects the parallel port by base I/O address.
Use *ScriptFileName*	Executes the named script.
Stop	Halts any currently active process.
Quit	Closes the application

3.3.2 Writing script files

The scripting feature allows you to execute a sequence of commands. For example, you could use this to run an automated sequence of tests, or to transfer a series of files to Flash memory.

To write a script file, type your commands into a text file.

You can also copy commands from the message log window (Section 3.4.1).

Each command must be placed on a separate line in the file.

>: 3. Transferring files

Unrecognized or misspelled commands are ignored. Execution continues with the next line in the script file.

Comments in script files

All text that isn't recognized as a command is assumed to be a comment.

For ease of reading, it is recommended that you surround comments in brackets. For example:

```
[This is a comment]
```

To comment a warning, prefix the comment with an exclamation mark:

```
![Stranger danger]
```

3.3.3 Executing script files

1. Configure the File Transfer Utility (Section 3.2.1).
2. Click the **Use script** button.
3. Browse and select the script file you want to use, or type
   `Use` *ScriptFileName*
   in the command prompt.

The progress bar will indicate the progress of the individual activity currently being executed (not the progress of the script file itself).

You can terminate a script at any time by clicking the **Stop** button.

3.4 Information in the message log

The message log appears in the right hand pane of the main File Transfer Utility dialog. Each new action causes some additional text to appear at the bottom of this window.

You can scroll through recent entries using Page Up and Page Down on your keyboard or by using the arrows or the hand on the scroll bar. The outer set of arrows takes you to the start or the end of the list.

The text in the message log is coloured according to its origin:

Green	-	Commands automatically generated by pressing buttons
Black	-	Commands typed manually at the command prompt
Purple	-	Messages generated by the parallel port handler
Blue	-	Messages generated by the board handler

>: 3. Transferring files

Grey	-	Intermediate messages or commands
Red	-	Error messages

3.4.1 Copying commands from the message log

You can copy commands from the message box onto a clipboard or into a text file. This allows you to create or add to script files.

Copying commands to a text file

1. Press the **Save** icon at the bottom right of the dialog. This will open the **Save As** dialog.
2. Select a name and location for the text file.

You can then execute the commands by using the text file as a script file (Section 3.3.3).

Copying commands to a clipboard

To save the contents of the message log window into a clipboard, press the **Copy** icon at the bottom right of the dialog.

>: 4. Using the example programs

>: 4 Using the example programs

4.1 Introduction

This chapter describes the example programs provided in the RC100 support software and describes how you can modify them. These programs demonstrate some of the features of Handel-C such as pipelining, channels and prialts.

4.1.1 Example programs

The RC100 support software contains the source code for three example programs:

- Menu Screen program – a simple program that demonstrates how to reconfigure the FPGA from files stored in Flash RAM.
- Text Editor program – a simple program that demonstrates how to interface with a keyboard and mouse
- Sobel Edge Detect program – a more advanced program that demonstrates how to use the FPGA for real-time image-processing. The program shows how to use two clocks set at different speeds.

4.1.2 Setting up DK1

In order to build the example programs you must set your environment variables to access the RC100 library and include files.

1. Start DK1 (For the default installation, select **Start**>**Programs**>**DK1 Design Suite>DK1**.)
2. Select the **Options** command from the **Tools** menu.
3. In the dialog that appears, select the **Directories** tab.
4. In the **Show directories for:** drop-down list, choose **Include files**. Click **Add**. In the dialog that appears, you may browse for the directory containing the RC100 include files or type the full pathname in the **Directories name** pane. The default path is **`RC100\Include`**
   For example, **`C:\Program Files\Celoxica\RC100\Include`**
5. Choose **Library files** from the **Show directories for**: drop-down list. Add the directories containing the RC100 libraries. By default, this path is **`RC100\Lib`**
   For example, **`C:\Program Files\Celoxica\RC100\Lib`**

>: 4. Using the example programs

4.1.3 Using the examples

To use the examples you will need to compile the programs and produce Xilinx BIT files:

1. Set up DK1 and set your environment variables to access the RC100 library and include files (Section 4.1.2).
2. Open the workspace for the example. The default location for the example programs is **`Program Files/Celoxica/RC100/Examples`**
3. Set the active configuration to EDIF (**Build>Set Active Configuration**)
4. Check that the correct device is targeted on the **Chip** tab in the **Project Settings** dialog. This should be **Virtex series Xilinx FPGA**.
5. Build the project. This will create a folder called EDIF within your project containing an EDIF netlist and a netlist constraints file (.ncf).
6. Use your Xilinx tools to place and route the netlist. If you are going to access the program from Flash memory on the board, you need to compile your application with Done Cycles equal to 6 and the start-up clock equal to CCLK. This is described in Section 4.1.4.
7. Use the File Transfer Utility to load the BIT file, and any associated data onto the board. This is described in more detail for each example program below.

4.1.4 Setting Done Cycles and the Start-up clock in Xilinx Design Manager

If you want to access programs from Flash memory (e.g. via the Menu Screen example program), you need to compile the programs with Done Cycles equal to 6 and the start-up clock equal to CCLK. You need to change this in the **Options** dialog in Xilinx Design Manager:

1. Open the **Options** dialog, and press the **Edit options** button for **Configuration** (the second **Edit Options** button). This will open a new dialog: **Spartan 2 Configuration Options: Default**.
2. Select the **Startup** tab, and change the value for **Done** to **C6** and the start-up clock to **CCLK**.

4.2 Menu Screen program

The Menu Screen program shows you how to:

- reconfigure the FPGA from files stored in Flash RAM
- use the RC100 board to interface with a monitor and a PS2 mouse
- edit and store a background image file
- use the Handel-C **`par`** statement for parallel processing

>: 4. Using the example programs

The menu screen has six designated areas that can be used to access programs in Flash memory on the board. If you place the mouse pointer over a designated area, its colour changes from white to yellow.

You can modify the example code to link programs stored in Flash RAM to these predefined areas, or to change the number and size of predefined areas.

Once you have linked programs to the predefined areas you can reconfigure the FPGA by clicking the left mouse button over one of these areas.

4.2.1 Loading the Menu Screen program

1. Open the workspace for the example in DK1 (**`menu.hw`**).
2. Compile the program and produce the Xilinx BIT file (see Section 4.1.2)
3. Connect a monitor and a mouse to the board. Set the monitor to a 640 * 480 display.
4. Choose the sector on the Flash RAM you want to load the BIT file to and then configure the other switches.
   For example, turn on switch 1 if you are loading to sector 1, or turn on switches 2 and 3 if you are loading to sector 6.
   (This is not necessary if you want to load the program to sector 0).
5. Use the File Transfer Utility (Section 3.2) to transfer the relevant files:
   First, load the background image for the program, **`menu.raw`**, to Flash location 0x380000 Note that this will overwrite whatever was previously stored in the Flash.
   Then transfer the BIT file to the chosen sector on the Flash RAM.

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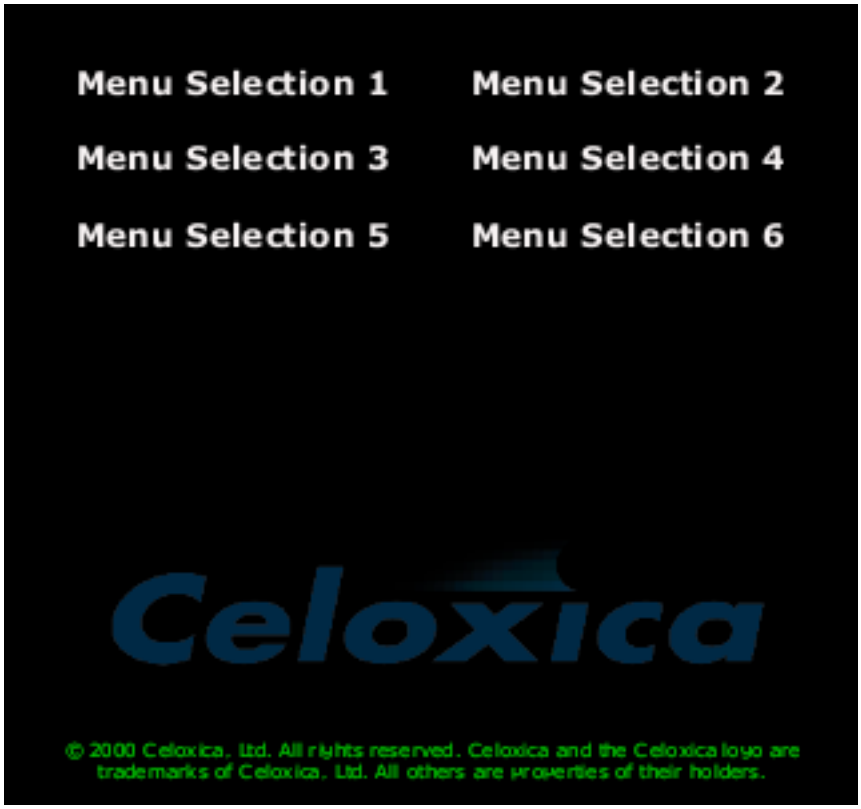
Menu Selection 1
Menu Selection 2
Menu Selection 3
Menu Selection 4
Menu Selection 5
Menu Selection 6
Celoxica
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4.2.2 Program structure

The **par** statement in the **main** function calls:

- The input macro (the mouse driver) **RC100PS2MouseDriver** from the RC100 library.
- The output macro (Video driver), **RC100VideoDriver**, from the RC100 library.
- The continuous macro procedures that run the program: **LoadImage**, **MenuSelection** and **Display**.

Since these macros, are all run in parallel with each other, operations on each pixel are performed at the same time as outputting them to the screen. This demonstrates the advantages that Handel-C gives over sequential languages like C.

Hardware drivers

The **RC100VideoDriver** generates the video output synchronisation and blanking periods. It is passed the pointer to the VGA structure.

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Each pixel takes one clock cycle. Then a blanking period occurs before the next frame is drawn to the screen.

The **RC100PS2MouseDriver** produces the feedback from the mouse. It is passed the pointer to the mouse structure and which PS2 port to use.

The precompiled library functions in the **RC100.lib** are described in more detail in the *RC100 Function Library Manual*.

LoadImage macro

The **LoadImage** macro loads an image file from a predefined area in Flash RAM and stores it in the SSRAM. The Flash RAM location is defined at the beginning of the source code and can be easily modified.

The macro reads each 8-bit colour element from a specified location in Flash RAM, and then stores the resulting 24-bit colour pixel.

The **LoadImage** macro is run before the **Display** and **MouseSelection** macros so that the memory is initialized before the output is displayed. This prevents unwanted data being displayed.

MenuSelection macro

The **MenuSelection** macro determines whether the mouse pointer is within one of the predefined areas. If this is true it sets an offset flag for the **Display** macro. It also checks whether the left mouse button is pressed. If it is, the FPGA reconfigures itself with a file from Flash RAM depending on which area was selected.

Display macro

The **Display** macro is pipelined into two parts that run in parallel. One part reads which colour should be displayed next from the RAM. The other part provides continuous output of the video signal, resulting in the colour being displayed on the screen. It also performs two calculations:

- It determines the location of the mouse pointer on the screen and displays the mouse pointer instead of the output signal in this area.
- If the mouse pointer is within one of the pre-defined areas that describe the files available for download, it offsets the colour before it is displayed. This changes the colour of the mouse pointer from white to yellow.

>: 4. Using the example programs

4.2.3 Modifying the program

If you want to add, remove or change items displayed in the menu program you need to:

1. Change the background image.
2. Save the image in raw file format.
3. Set the coordinates for any new menu items, or change the coordinates to fit the length of the text inserted for a menu item.
4. Specify the start location of the Flash for each program accessed from the menu at the beginning of the menu.c file.
5. Recompile the program and transfer the new files to the board, as described in Section 4.2.

Changing the background image

You need to change the background image of the menu screen example to specify the names of the programs you wish to access from the menu.

The background image, **`menu.raw`**, is stored in 24-bit Raw File Format. It does not contain header information and is interleaved in the following format (RGB RGB…). The image is also provided in a Paint Shop Pro file format (**`menu.psp`**), which may be easier to modify.

To change the background image:

1. Make changes to the image file using a graphics editor. Alternatively you can substitute a new image.
2. Save the new image in Raw File Format. If you do not have any software that can save as Raw File Format you can save as a bitmap and use the bmp2raw utility described in Appendix A.
3. Transfer the new file to Flash RAM using the File Transfer Utility.

Graphic files loaded from Flash RAM use a 24-bit Raw File Format without header information. Other formats will not work with this program.

Saving the image in raw file format

If you do not have any software that can save as Raw File Format you can save as a bitmap and use the bmp2raw utility provided in the support software (see Appendix A).

Setting coordinates for a new item on the menu

The **`SetArea`** macro is used to set the coordinates of menu items in the ROM. These coordinates describe an imaginary box around each menu item. For example, the

coordinates for Menu Selection 1 are the top left corner (40, 35) and the bottom right corner (235, 60). This translates to the following line in the code:

```
SetArea(40, 35, 235, 60)
```

The order in which the items are stored in the RAM determines the configuration vector sent to the Flash RAM.

To set the coordinates for a menu item:

- Map an arbitrary box around it by entering the coordinates into the **`SetArea macro.`**

4.3 Text Editor program

The Text Editor program allows you to enter text and simple commands with a keyboard, and to change the colour of text. It displays the results on a VGA screen. Both the mouse and keyboard can control the cursor.

Once you have started the program you can:

- move the cursor by left-clicking anywhere in the white area of the screen
- enter text at the cursor
- change the colour of subsequent text by clicking one of the colours at the bottom of the screen
- use simple keyboard commands

The keyboard commands recognized by the program are:

- Text-editing: Return; Backspace; Delete; Ctrl-Alt-Del. Ctrl-Alt-Del clears the screen.
- Cursor control: left, right, up and down arrows; Home; End; Ctrl-Home; Ctrl-End.

All other keyboard keys are ignored.

The Text Editor program shows you how you how to:

- use the RC100 board to interface with a monitor, PS2 mouse and keyboard
- use the Flash RAM on the board
- use the Handel-C **`par`** statement for parallel processing

4.3.1 Loading the Text Editor program

1. Open the workspace for the example in DK1 (**`TextEditor.hw`**).

>: 4. Using the example programs

2. Compile the program and produce the Xilinx BIT file (see Section 4.1.2).
3. Connect a monitor, a mouse and a keyboard to the board. Set the monitor to a 640 * 480 display.
4. Use the File Transfer Utility (Section 3.2) to transfer the relevant files:
   First load the font file **`font.raw`** to Flash location 0x300000. Note that this will overwrite whatever was previously stored in the Flash.
   Then transfer the BIT file to the FPGA.

Welcome to the Celoxica FPGA test editor demonstration.
This text editor is a circuit on an FPGA. It was designed and developed using Handel-C.

4.3.2 Program structure

The **`par`** statement in the **`main`** function calls:

- The input macros (the mouse and keyboard drivers), **`RC100PS2MouseDriver`** and **`RC100PS2KeyboardDriver`**, from the RC100 library.
- The output macro (Video driver), **`RC100VideoDriver`**, from the RC100 library.
- The continuous macro procedures that run the program: **`Initialise`**, **`KeyboardInterface`**, **`Write`**, **`MouseClick`** and **`Display`**.

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Since these macros, are all run in parallel with each other, operations on each pixel are performed at the same time as outputting them to the monitor. This demonstrates the advantages that Handel-C gives over sequential languages like C.

Hardware drivers

The **RC100VideoDriver** generates the video output synchronisation and blanking periods. It is passed the pointer to the VGA structure.

Each pixel takes one clock cycle. Then a blanking period occurs before the next frame is drawn to the screen.

The **RC100PS2MouseDriver** produces feedback from the mouse. It is passed the pointer to the mouse structure and which PS2 port to use.

The **RC100PS2KeyboardDriver** produces feedback from the keyboard. It is passed the pointer to the keyboard structure, which PS2 port to use, and a description output format to use.

The precompiled library functions in the **RC100.lib** are described in more detail in the *RC100 Function Library Manual*.

Initialise macro

The **Initialise** macro initializes the SSRAM bank 0 to spaces (0x20). This clears the screen of unwanted characters. The second part of this macro loads the font file from Flash RAM, and stores it at the beginning of the SSRAM.

The fonts are stored as bitmaps and are read from memory when they are displayed. Their location in Flash RAM is defined at the beginning of the source code and can be easily modified.

The **Initialise** macro is run before the other macros so that the memory can be successfully initialized before the output is displayed. This prevents unwanted data being displayed.

KeyboardInterface macro

The **KeyboardInterface** macro determines what to do with the data returned from the keyboard. The program waits for input from the keyboard passed via a channel. After this has been received it checks whether the character is a control character or an ASCII character.

If it is a control character the program runs a switch statement and performs the appropriate action. For example, if ‘Home’ is pressed the cursor is returned to the left side of the screen.

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If the input is a valid ASCII character it will be stored in the appropriate location in RAM and the cursor will be moved to the next position.

Write macro

The **`Write`** macro stores the ASCII characters. This is a protected write, meaning that if the memory is in use, it will wait until it is free before writing. This prevents multiple accesses on the same clock cycle that would otherwise corrupt the data.

MouseClick macro

The **`MouseClick`** macro determines what to do when mouse buttons are pressed. There are three parts to this macro:

- If the right mouse button is pressed the FPGA reconfigures itself with whatever program is stored in Flash RAM at location zero. This is usually a menu program resulting in the menu screen being displayed on the VGA.
- If the left mouse button is clicked on the colour palette the macro changes the cursor colour and the text to the selected colour, starting with the next character to be typed.
- If the left mouse button is pressed anywhere in the text area, the cursor will be repositioned to that location.

Display macro

The **`Display`** macro is pipelined into two parts that run in parallel. One part loads the ASCII character specified by input from the keyboard from RAM and works out which part of the bitmap to display in each clock cycle. As each character is 8 bits wide the process is broken down to two sequential processes running in parallel and lasting 8 clock cycles. The other part of the macro provides the output signal. It calculates whether the mouse pointer or the result from the first part of the macro should be displayed.

4.3.3 Modifying the program

Adding more keyboard functions

The Text Editor program recognizes 12 control characters. These are listed in the **`switch`** statement in the **`KeyboardInterface`** macro procedure in **`editor.c`**

`ASCIIChars.h` lists additional control characters which have been assigned. You can add these functions to theText Editor program by adding them as new cases in the **`switch`** statement. For example, to add in the “Insert” control:

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```
case ASCII_CTRL_INSERT:
                par
                {
                   // Enter your code here
                }
                break;
```

Only ASCII codes 0-127 are supported for this program. This means you cannot use the function keys, number pad keys, or Print Screen, Scroll or Pause/Break.

Adding text selection with the mouse

Text selection (highlighting text with the mouse) could be used as part of a text editing function. For example, you might want to select text before cutting and pasting it elsewhere.

To add this feature you need to:

1. Edit the **MouseClick** macro, so that when you click and drag the mouse, a region is selected. You need to specify starting and end coordinates for the action.
   - Store the start coordinates from the point where the user first clicks the left mouse button.
   - Store the end coordinates from the point where the user releases the left mouse button.
2. Edit the **Display** macro to add a function that inverts the colour output within the selected area.

4.4 Sobel Edge Detect program

The Sobel Edge Detect program demonstrates the use of Handel-C in a real time image processing application.

Video data is read from a camera and a Sobel Edge Detection algorithm is applied to the data. The results are output to a VGA screen.

The program compares groups of pixels with their immediate neighbours. If there is no difference, nothing will be shown on screen. If there is some difference (e.g. different shades of grey), a faint “edge” will be seen. Distinct changes in colour will show up as a clear “edge” on the screen.

The Sobel Edge Detect example program shows you how to:

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- Process video input from a camera, using the Philips SAA7111A Enhanced Video Input Processor (EVIP) on the RC100 board.
- Use two separate clocks running at different clock speeds.
- Communicate between clock domains using channels.
- Use multi-port block RAMs to buffer data.
- Use a pipeline to optimize code.

The program has a modular design, allowing you to add, change or remove functions. For example, you could remove the display process and add in some further image processing functions.

4.4.1 Loading the Sobel Edge Detect program

1. Open the workspace for the example in DK1 (EdgeDetect.hw).
2. Compile the program and produce the Xilinx BIT file (see Section 4.1.2)
3. Connect a monitor and a video camera to the board. Set the monitor to a 640 * 480 display.
4. Transfer EdgeDetect.bit to the chosen sector on the FPGA using the File Transfer Utility (Section 3.2).

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4.4.2 Program structure

The operation of the program is shown below. Processes running within the FPGA are denoted using circles. Lines with arrowheads represent channels between two processes; the arrowheads indicate the direction in which data is sent down the channel. A line with no arrowhead indicates a simple connection to a device.

The design is split into two clock domains, shown by a dotted line on the diagram.

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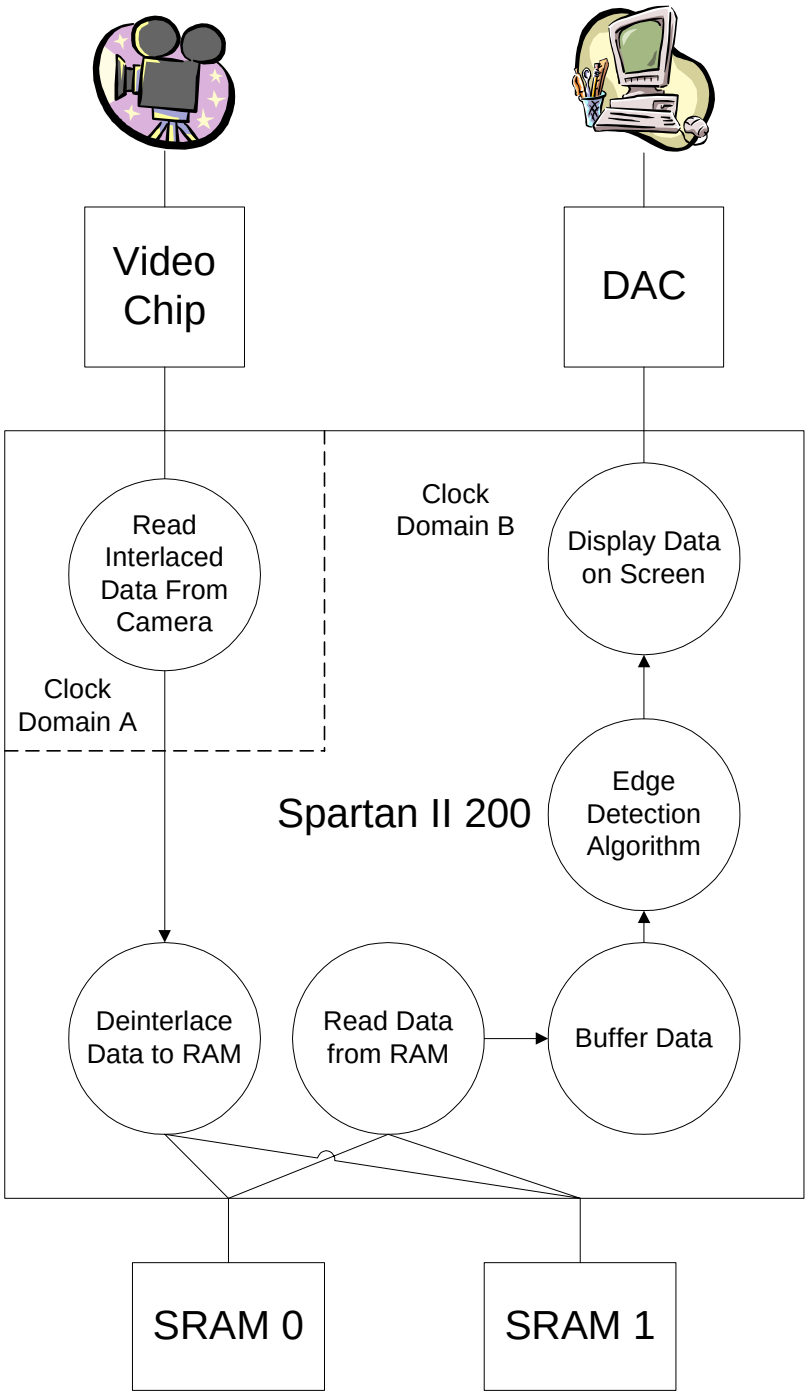

HIGH-LEVEL DESIGN OF THE SOBEL EDGE DETECT PROGRAM

>: 4. Using the example programs

Using multiple clock domains

The interface to the video decoder chip is clocked at the same speed as the clock on the chip (27MHz). The rest of the FPGA is clocked by the main oscillator running at 80MHz. This is divided by three or four, depending on which Handel-C program is running. More information on the use of clocks with Handel-C is given in the *Handel-C Language Reference Manual* in the DK1 online help.

4.4.3 Reading and storing data input

Reading input from the camera

The Edge Detect program uses the **`RC100VideoDecoder`** driver from the RC100 library to read data input from the camera.

Communication between clock domains

A FIFO buffer, implemented in block RAM, passes data between the two clock domains. Synchronisation is achieved using Handel-C channels, which abstract away from the programmer the complexities of communication between different clock domains.

Writing data into SSRAM

The input data from the camera is interlaced. This needs to be de-interlaced before the data is stored in the SSRAM. The input data from the process reading from the camera clock domain contains positional information so that the lines can be written to the correct location.

Once a frame is complete, the reading process reads the de-interlaced data from this RAM bank whilst the de-interlacing process switches to the other SSRAM bank to write the next frame. The de-interlacing process sets a 1-bit variable to control which RAM bank is being written to.

4.4.4 Processing and displaying stored data

Reading data from SSRAM

This process uses the **`RC100ReadSSRAM0`** driver from the RC100 library to read an image out of the SSRAM. The image is equal in size to the visible area of the screen, set by constants from the RC100 video library.

The reading process switches between the two RAM banks, to alternate with the writing process described above.

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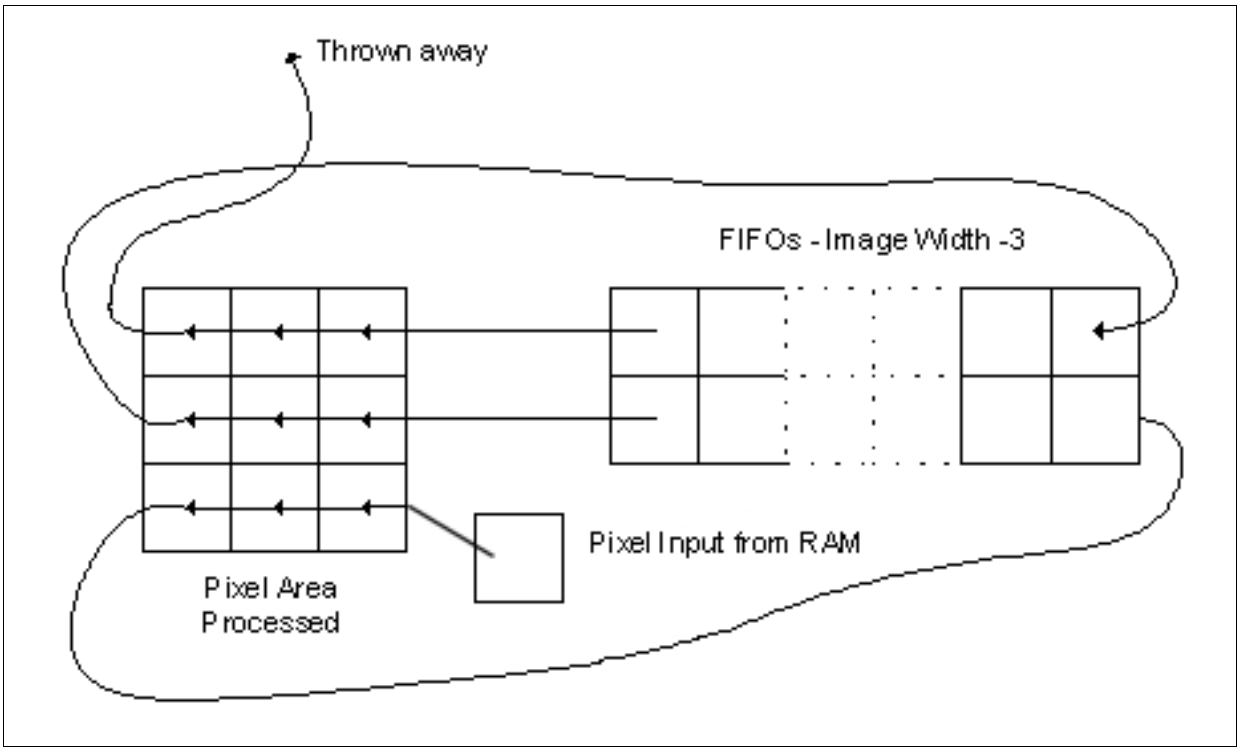
Buffer management

Spatial image filters, such as Sobel Edge detection, operate on a square area of pixels from an image. The Sobel Edge Detect program operates on a 3 by 3 pixel area. In order to access a 3 by 3 area of an image in a single clock cycle, data from the RAM needs to be stored in buffers.

The process for updating the buffers is implemented using replicated **`par`** statements. This means you can easily extend the code for different size matrices.



The buffer management process takes an input of one pixel from a channel and outputs a 3-by-3 array down a channel to the image-processing algorithm every clock cycle.

Two FIFO buffers are used. Each stores a line of the image, minus the three pixels that are stored in the array. Every clock cycle, a pixel received from the RAM reading process is put into the bottom right corner of the array. The contents of the array are shifted to the left, with the leftmost member being added to the tail of the FIFO. The top left pixel is now finished with and can be written over without storing it anywhere else.

The FIFOs are implemented using circular buffers constructed from multi-port block RAM with an index keeping track of the front item in the buffer.

The availability of multi-port block RAM in the Spartan II FPGA means that you can read and write to the RAM in the same clock cycle. This allows a throughput of one pixel per clock cycle. The same effect can be achieved using double-width RAMs implemented in lookup tables on the FPGA. However, the use of block RAMs is more efficient and has less associated logic for reading and writing.

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Edge detection algorithm

In this example code, each colour is processed individually and the results make up a single pixel. 3 by 3 arrays for each colour arrive down the input channel and 16 bit pixels are output.

A wrapper process (**`ProcessVideo`**) takes pointers to an input channel, an output channel and the image processing function as arguments. A constant integer value parameter is also passed to the wrapper function. This constant is the number of clock cycles that the image processing function takes to produce an output at the end of the pipeline from an input.

The image processing function (**`ProcessWindowSobel`**) takes a pointer to the set of three 3 by 3 arrays representing the three colours of the 3 by 3 area of the image as one parameter, and a pointer to a 16 bit pixel as the second, into which the output will be written. This means you can substitute a new image processing function without needing to make any changes to the rest of the code.

Sobel edge detection is performed using two 3 by 3 matrices, one for horizontal edges and one for vertical edges. The two 3 by 3 matrices are shown below. The results of the application of these two matrices to the 3 by 3 area of the image are then added together to produce the final output.

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Sobel operators (x and y direction)

The algorithm used in this program has been pipelined to produce one pixel every clock cycle. The output for a given input appears at the other end of the pipe several clock cycles later.

The algorithm has been implemented using a Handel-C macro procedure (**`Sobel`**). Macro procedures are an alternative to functions in Handel-C and implement direct code replication. They allow programmers to imply word width and sign and to use different widths with each call to the macro. The **`Sobel`** macro procedure performs the same edge detection algorithm on the red, green and blue components, even though the green component is a 6-bit number and red and blue are 5-bit.

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Displaying data on the screen

The **`RC100VideoDriver`** macro is used to generate scan data. When the current scan position is within the visible area, the display process reads a pixel from its input channel.

4.4.5 Pipelining the data processing

The Sobel Edge Detect program uses a complex pipeline to accelerate the processing of data.

Each of the processes below uses the scan position of the screen to ensure that they carry out actions at the correct time:

- Reading process: reads an image the size of the visible area of the screen from the SSRAM bank not being used by the writing process.
- Buffer process: copies information from the reading process into the buffers and shifts data through the buffer at the right time so that valid (visible) data is input at one end and output at the other
- Image processing process: takes data at the correct time from the buffers and passes the output to the display process
- Display process: reads output from the image processing process and displays it when it is required on the screen.

Possible solution

You could make process keep track of its own scan position. Each process would need to calculate when the information that it reads and writes is visible and stall when it is not.

Two disadvantages of this are:

- The work required in calculating the pipeline delays
- The overhead of each process keeping track of its own scan position.

Efficient solution

An alternative approach is taken in the Edge Detect program. Each process produces the data that the process downstream needs and blocks when the downstream process is not ready to accept data.

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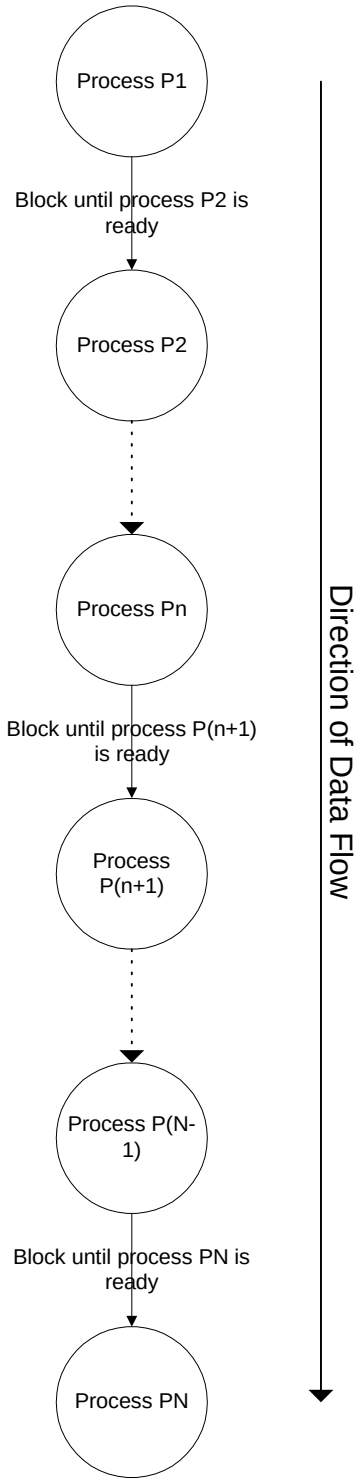

PIPELINING PROCESS

>: 4. Using the example programs

In the Edge Detect program, the display process is furthest downstream and so this stalls the pipeline when it is not ready to take data. The display process only needs to take data when the current scan position is in a visible area of the screen.

Achieving synchronisation

Synchronisation is achieved using a combination of signals and channels. The **ProcessVideo** function, shown below, copies data over a number of clock cycles to the output.

```
/*
      inputs: WindowInChan - pointer to a 16 bit channel for incoming
      data
      outputs: OutChan - pointer to a 16 bit channel for outgoing data
      process: pipeline to add latency to the propagation of data
*/
void ProcessVideo(chan WINDOW_PIXEL_16 *WindowInChan, chan unsigned 16
            *OutChan, const unsigned ProcessDelay, void
            (*ProcessWindow)(WINDOW_PIXEL_16 *Window, unsigned 16 *Pixel))
{
      //window read in from input channel
      WINDOW_PIXEL_16 Window;
      //pixel to output
      unsigned 16 Pixel;
      /*
      signal indicating whether or not data has been sent on a clock
      cycle
*/
      static signal unsigned 1 NoDataSent = 0;
      //counter to delay the output of data while the pipe is primed
      unsigned DelayCounter;

      //read in the first window (blocks until data is available)
      *WindowInChan ? Window;
```

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```
par
{
   while(1)
   {
      //if data has been sent
      if (!NoDataSent)
      {
         par
         {
            //read in a new window
            *WindowInChan ? Window;
            //process the window
            ProcessWindow(&Window, &Pixel);
         }
      }
      else
         delay;
   }


   {
      //delay until the pipeline is primed
      do
      {
         DelayCounter++;
      }
      while(DelayCounter!=(ProcessDelay+1)-1);

      /*
         send the data to the next process in the pipeline
         if the send blocks, pause the pipeline update by
         setting NoDataSent to 1
      */
      while(1)
      {
         prialt
         {
            case *OutChan ! Pixel: break;
```

>: 4. Using the example programs

```
                default: NoDataSent = 1; break;
            }
        }
    }
}
```

The **ProcessVideo** function reads its input from the channel referenced by the pointer **WindowInChan** and writes to the channel referenced by the pointer **OutChan**. If the receiving channel is not ready to take the current data, the process stalls until it is.

A **prialt** statement is used ensure that the pipeline is not updated if a process has stalled. In the **prialt** statement, the first case tries to send the output to the next process. If the process is not ready to take the data, the default case of the **prialt** statement is executed, setting a signal high. This signal is used to check whether or not to update the pipeline in the same clock cycle. This code is highlighted in grey.

Hardware efficiency of prialts and signals

The **prialt** code block may look large, but it is extremely efficient.

Channels have what can be thought of as two wires, one from each side of the communication, to indicate readiness. The **prialt** with a single **case** and **default** on the sending side is implemented with a single-bit comparator, (as for a normal channel communication), with the branch for an unsuccessful transmission setting the signal high. The signal is implemented as a single wire with a single bit comparison in hardware.

4.4.6 Modifying the program

The Edge Detect program is modular, which means you can substitute, add or remove processes. Some examples are given below.

Using a different image processing algorithm

You can substitute the call to the Sobel edge detection macro with a call to a different spatial image processing macro.

It is important that you calculate the latency in clock cycles of the image processing process correctly; otherwise erroneous data will appear in the output.

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Adding stages to the pipeline

You can add extra pipeline stages by inserting a new function between two others in the pipeline. For example you could add an image processing function (with its own buffers) that smoothed the picture before the edge detection algorithm was performed.

The new function needs to copy the method of communication used in the other functions. A template function is provided. This reads from a channel and copies the data into the output channel.

It is important that the pipeline delay is calculated correctly; otherwise errors from later or earlier data will filter downstream.

Pipelining multiple image processing functions

You can pipeline a number of image processing functions:

1. Take the output of one image processing function.
2. Copy it into a buffer for the next image processing function.
3. Process the output of the buffer.

Each set of buffers requires the use of multiport RAM, so there is a limited number of functions that can be pipelined. An alternative is to use buffering that uses 32-bit wide RAMs constructed from lookup tables on the FPGA, which can then be read and written in alternate clock cycles.

Interpreting the data output from the edge detection

The Sobel Edge Detection program displays the results of the image processing on the screen, but many applications need to interpret this data in order to make an analysis of the image. The way in which the RAM is used in this application makes it difficult to do a significant amount of interpretation, as the processed data is not stored in RAM.

Greyscale vs. full colour

The example code is written for full colour image processing, but you can adjust it to do grey scale image processing. Greyscale image processing will reduce the amount of data storage and logic produced.

In order to create the most efficient program possible, the grey scaling should be done at the earliest moment – as soon as a pixel is read from the camera. This will reduce the amount of RAM used to store a pixel, the size of registers for the pipeline stages and thus the logic needed to manipulate the data through the pipeline. It should also be possible to pipeline more image processing operations, as the buffers for storing the data will be smaller.

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Appendix A. Bitmap / raw file format utilities

5.1.1 Introduction

The Text Editor program only accepts images that are in raw file format. However, images in BMP format may be easier to edit. The RC100 support software contains two utilities that allow you to convert between these formats.

bmp2raw	converts BMP images to raw file format
raw2bmp	generates BMP image files from files in raw format. These may be easier to modify with graphics editors.

5.1.2 How to use the raw file / bitmap utilities

bmp2raw utility

The general usage of the bmp2raw utility is:

bmp2raw [-b] *BMPFile RAWFile RGBFile*

BMPFile	source image file
RAWFile	destination raw data file
RGBFile	file describing the format of the pixels in the raw data file

The format of the raw data file can be controlled with the *RGBFile* specified on the command line. This tells the utility where to place each colour bit in the words in the raw data file. Internally, the pixels in the BMP file are expanded to 8 bits for each of red, green and blue. The RGB description file has the general format:

Red

Location for bit 7 of red
Location for bit 6 of red
Location for bit 5 of red
Location for bit 4 of red
Location for bit 3 of red

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Location for bit 2 of red
Location for bit 1 of red
Location for bit 0 of red

Green

Location for bit 7 of green
Location for bit 6 of green
Location for bit 5 of green
Location for bit 4 of green
Location for bit 3 of green
Location for bit 2 of green
Location for bit 1 of green
Location for bit 0 of green

Blue

Location for bit 7 of blue
Location for bit 6 of blue
Location for bit 5 of blue
Location for bit 4 of blue
Location for bit 3 of blue
Location for bit 2 of blue
Location for bit 1 of blue
Location for bit 0 of blue

The file works by starting counting at bit 7 of the colour specified by the identifier word and works down through the bits of that colour placing each bit in the specified location in the destination word. The destination word will automatically be created wide enough to contain the most significant bit specified (up to 32 bits wide in total).

You need not specify 8 locations for each colour. The least significant bits of each colour will be dropped if fewer than 8 locations are specified. In the example below, the least significant 6 bits of red and blue and the least significant bits of green are dropped.

To generate 8-bit pixels in the raw file with the following bit pattern:

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Raw file bit number	Colour bit
7 (Most significant)	Red 7
6	Green 7
5	Blue 7
4	Blue 6
3	Green 6
2	Red 6
1	Green 5
0 (Least significant)	Green 4

use the following *RGBFile*:

```
Red
7
2
Green
6
3
1
0
Blue
5
4
```

Each pixel number and identifier (**`Red, Green or Blue`**) must appear on a separate line.

You may also specify multiple identifiers of the same colour. The bit counter will continue to count down from the value reached for that colour each time you specify the colour again. For example, the above file could also be written like this:

```
Red
7
Green
6
Blue
5
Red
2
Green
3
1
```

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```
Blue
4
Green
0
```

raw2bmp utility

The raw2bmp utility is the reverse of the bmp2raw utility. It converts binary files to BMP image files.

The general usage of the raw2bmp utility is as follows:

raw2bmp [-b] *Width RAWFile BMPFile RGBFile*

Width	the width of the image. The height will be calculated from this parameter and the source file length.
RAWFile	source file containing raw data.
BMPFile	destination image file.
RGBFile	file describing the format of the pixels in the raw data file.

The format of the *RGBFile* describing where each bit is located in the raw data word is similar to the file used by the **bmp2raw** utility. Indeed, for some pixel formats (such as in the example presented in the previous section) a common file may be used.

As an example of where a different file may be required, consider the conversion of 8 bit per pixel greyscale images to a BMP image. Here, each bit must be duplicated in the red, green and blue components of the destination BMP file. For example:

```
red
7
6
5
4
3
2
1
0
green
7
6
5
4
```

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```
3
2
1
0
blue
7
6
5
4
3
2
1
0
```

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Appendix B. Location of demos in Flash RAM

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Block	Start Address	Contents	Configuration Vector
0	00000000	Intro GUI configuration file	0
1	00020000	Intro GUI configuration file	0
2	00040000	Venus	1
3	00060000	Venus	1
4	00080000	Breakout	2
5	000A0000	Breakout	2
6	000C0000	Squish	3
7	000E0000	Squish	3
8	00100000	Video	4
9	00120000	Video	4
10	00140000	Celoni Racer	5
11	00160000	Celoni Racer	5
12	00180000	Windows	6
13	001A0000	Windows	6
14	001C0000	Boat Game	7
15	001E0000	Boat Game	7
16	00200000	(unused)	8
17	00220000	(unused)	8
18	00240000	Squish Image	9
19	00260000	Squish Image	9
20	00280000	Squish Image	10
21	002A0000	Squish Image	10
22	002C0000	Squish Image	11
23	002E0000	Squish Image	11
24	00300000	Font.raw file	12
25	00320000	Celoni Map	12
26	00340000	(unused)	13
27	00360000	(unused)	13
28	00380000	spans	14
29	003A0000	spans	14
30	003C0000	spans	15
31	003E0000	spans	15
32	00400000	spans	16
33	00420000	spans	16

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34	00440000	spans	17
35	00460000	spans	17
36	00480000	spans	18
37	004A0000	spans	18
38	004C0000	spans	19
39	004E0000	spans	19
40	00500000	spans	20
41	00520000	spans	20
42	00540000	spans	21
43	00560000	spans	21
44	00580000	spans	22
45	005A0000	spans	22
46	005C0000	spans	23
47	005E0000	spans	23
48	00600000	spans	24
49	00620000	spans	24
50	00640000	spans	25
51	00660000	spans	25
52	00680000	spans	26
53	006A0000	spans	26
54	006C0000	spans	27
55	006E0000	spans	27
56	00700000	Mask	28
57	00720000	Mask	28
58	00740000	Embossing	29
59	00760000	Embossing	29
60	00780000	Text Overlay	30
61	007A0000	Text Overlay	30
62	007C0000	Swirly Background	31
63	007E0000	Swirly Background	31

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